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Ives. A. W. with the respects of the Author

AN

EXPERIMENTAL INQUIRY

INTO THE

PROXIMATE CAUSE OF DEATH

FROM

SUSPENDED RESPIRATION

IN

DROWNING AND HANGING,

WITH THE MEANS

OF

RESUSCITATION.

SUBMITTED AS AN INAUGURAL ESSAY TO THE PUBLIC EXAMINATION OF THE TRUSTEES AND PROFESSORS OF THE COLLEGE OF PHYSICIANS AND SURGEONS IN THE UNIVERSITY OF THE STATE OF NEW-YORK,

SAMUEL BARD, M. D. PRESIDENT,

FOR THE

DEGREE OF DOCTOR OF MEDICINE

On the 3d of May, 181[illegible]

BY ANSEL W. IVES

Honorary Member of the American [illegible] Society.

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TO

VALENTINE MOTT, M. D.

Professor of the Principles and Practice of Surgery in the University of the State of New-York, Corresponding Member of the Medical Society of London, &c. &c.

THIS humble Essay is respectfully inscribed as the only tribute in the Author's power to offer, for private friendship, and professional instructions, which no tribute, however ample, could compensate.

That the success of DOCTOR MOTT, in his professional pursuits may be equal to his merit, and that the first disposition of his heart—the desire of doing good to his fellow-men, may be fully gratified, will ever be the first wish of his

Sincere friend, and

grateful Pupil.

ANSEL W. IVES.

TO

DOCTOR BARTOW WHITE,

PRESIDENT OF THE DUTCHESS MEDICAL SOCIETY, NEW-YORK;

DOCTOR ELISHA NORTH,

NEW LONDON, (CONN.)

AND

DOCTOR ERASTUS L. HART,

GOSHEN, (CONN.)

THIS DISSERTATION

IS MOST RESPECTFULLY DEDICATED BY THEIR

GRATEFUL FRIEND AND PUPIL,

THE AUTHOR.

AN

EXPERIMENTAL INQUIRY, &c.

The investigation of the proximate cause of death in Suspended Respiration from Drowning and Hanging, is difficult and abstruse, as it immediately involves the consideration of the essential principles of life. Not to dwell on the incomprehensible connection between mind and matter; and the mysterious law by which one operates upon, and vivifies the other; not to deal in speculations too deep and refined for the human intellect to grasp, let us for a moment, advert to the complexity of the human machine, considered as matter alone. We see a machine operated on by a power which we cannot define cannot examine cannot comprehend. Let us, therefore, dismiss this invisible agent, and confine ourselves solely to that machine. Every part of this curious piece of mechanism is essential to the perfect operation and unabated energy of the whole: one part in a greater, another part in a lesser degree. But our greatest inquiry is, what parts are, and what parts are not essential to its operating at all.

By determining on these, we shall find those principles on which life most immediately, and in the strictest sense essentially depends; and of course the cause of those disorders which instantly stop the vital action of the human frame. This subject is not less

important, than curious and interesting. In those disorders of our slender machine which produce their effect slowly, there is time for the Physician, who may be called the human mechanist, to study their cause, and to vary his expedients; but where the vital functions are instantaneously suspended, the effort must be immediate. Stop to consider, and the patient is irrevocably lost.

Those vital functions upon which life so immediately depends, were formerly supposed to be the Brain, the Heart, and the Lungs. The Brain was considered as the only source of nervous power; that is, the only source of motion, and sensation. But many phenomena were found inconsistent with this Theory, as for example, the life which remained in decapitated animals, and in the heart when detached from the body. To obviate this difficulty a fourth power was added by Haller, denominated *vis insita*, a mysterious principle which no one pretended to understand, and which might therefore be made a safe head of reference for every incomprehensible phenomenon. Thus the explanations of philosophy are often more unintelligible than the facts she attempts to explain, and when she cannot enlighten, she shrouds her subject in deeper mystery.

In the course of this essay, I shall attempt to show, that there is a fourth vital organ which has been but recently understood; the functions of which, will explain all the phenomena formerly attributed to the *vis insita*; and therefore as there is no longer any need of this mysterious principle, the offspring of Hypothesis, it is, or ought to be exploded. But before I attempt this, it will be necessary briefly to state the Hallerian doctrine.

Taking it for granted that the Brain was the only source of nervous power, Haller supposed that the nerves and the Spinal Marrow which he considered as a larger nerve, were the agents

by which the brain performed its office. He also supposed that the muscles possessed a contractile power, or disposition to contract, which he called *irritability* or *vis insita.* All animal motion was attributed by him to this contractile power, acted upon by a stimulus, the stimulus being different according to the muscle on which it was to act. Thus he supposed the muscles which are submitted to the control of the will, and therefore called voluntary muscles, are stimulated to act by the Brain through the medium of the nerves; but those muscles which contract independent of the will, do not in any measure depend on the nervous power, as the Heart and Stomach for example, which are supposed to be stimulated by their respective contents, without any aid or agency of the nerves. This Theory accounts in a beautiful manner for the action of those muscles *in coma* when the will is sleeping on its post. But however ingenious and convenient the theory, it never fully satisfied either Haller or his Disciples—various modifications were introduced and even facts were controverted. Difficulties, inexplicable, were involved in the theory itself, and removing one absurdity, only introduced another. It was denied for instance, that the heart possessed any nerves; and though this removed, the Heart entirely from the influence of the Brain, and gave it up wholly to the *vis insita;* yet it introduced another absurdity—that the Heart could be operated upon by the passions, without the intervention of nerves.

As the science of Anatomy advanced; as the distribution and connection of the nerves were better understood; and the functions of the vital organs more clearly defined, difficulties in the way of this doctrine multiplied.

The medical profession are in the highest degree indebted to M. Bichat, for the light he has thrown on this subject. Though in his physiological researches, he did not hit upon the novel ideas of Le Gallois, his experiments actually tended to the same con-

clusion, contrary as that conclusion was, to own belief. To attempt to overthrow a doctrine so well established and supported by the great body of the profession, required more than ordinary boldness; yet it found opponents in men distinguished for science and talents. The difficulties which embarrassed it, would, in spite of prejudice, predilection, and the fear of ridicule, force themselves on the mind of the original thinker, and compel him to doubt. As an instance of the dissatisfaction which ingenious and reflecting men felt with this theory, and of the advances which were making to the true hypothesis, I insert the following extract from a manuscript lecture of *Doctor Hosack*, delivered at Columbia College, in this City, 1798:

After describing the distribution of the nerves, he adds, "seeing, therefore, this universal distribution of the nerves through the different parts of the body—the means by which the capacity of performing their functions is preserved, and the numerous connections which takes place between the nerves of the various and distant parts of the body, by means of the great sympathetic nerve, and by plexus, we *infer the presumption, that they serve the great purpose of supplying the body, not only with sensation, but motion; and that the vis insita is unnecessary for this purpose.*"

But without multiplying authorities, it will be sufficient, briefly to state, that in 1809, Dr. Le Gallois, a distinguished French physiolygist, performed his experiments on the principles of life. He took a path untrodden by former anatomists. The discoveries which he made, were wonderful, and such as have caused, or will cause, an entire revolution in the theory of the vital functions.

From all his experiments he deduces the following principles: That the brain is the organ of intelligence, but not as Haller supposed of sensation and motion.

That the only part of the brain which is immediately essential to life, is that portion of the medulla oblongata, from which the *par-vagum*, or eighth pair of nerves arises, viz: the *Corpora Olivaria.*

That if this portion of the medulla oblongata be preserved, life will not be destroyed, though the remainder of the brain be dissected off.

That this portion of the Brain is essential to life in a two fold capacity.

1st. As the origin of the eighth pair of nerves, which are distributed to the Heart, the Stomach and the Lungs, and upon which the functions of the Lungs exclusively depend; and,

2dly. As it gives influence to the nerves which supply the respiratory muscles.

That the Medulla Spinalis is the source of sensation and motion, independent of the Brain, and that if artificial respiration be kept up in decapitated animals, life will be preserved.

But as the Brain is the residence of the intellectual functions, the motions of the body, in this case, will be accidental, and not under the control of the will.

That the life of every portion of the body depends upon the nerves of a corresponding portion of the Spinal Marrow, and hence if the Spinal Marrow be cut into different sections, each section will be a distinct center of sensation and motion.

That the Heart receives its principles of life and of power from the Medulla Spinalis, but not like the trunk from a limited portion of it, but from the whole.

Hence if any portion of the Spinal Marrow be destroyed, the force of the Heart will be weakened, but if the whole be destroyed, its action will suddenly cease.

That this influence which the Medulla Spinalis exercises over the Heart, is through the medium of the great sympathetic nerve.

That as this nerve arises from every portion of the Medulla Spinalis, and not like the nerves supplying every other part of the body, from a single point, it serves to explain why the action of those organs to which it is distributed, is uninterrupted and involuntary.

That the action of the Heart is not more dependent upon the nervous power than the nervous power is upon the blood.

That if a portion of the aorta be included in ligatures, a paralysis of the corresponding portion of the body ensues.

Finally he concludes, that the Brain and Spinal Marrow are the sources of sensation, and motion, in short; of every thing which constitutes life; and that life is produced, and maintained, by the impression of arterial blood upon these organs.

Thus we see that to support life, a reciprocity must be maintained in these functions, the destruction of which is always the *proximate*, whatever may be the remote cause of death.

We have said that the Brain and nerves were excited to action by the impression of arterial blood. But this blood in its passage through the arteries from the left side of the heart to the most extreme parts of the body, and in its return through the veins to the right side of the heart, acquires a superabundance of carbon. This has the effect of changing it from the florid colour observed in the arteries, to the dark purple it exhibits in the veins. But what is more important, it is by this means rendered unfit for the

purposes of nutrition, and secretion, and its stimulating effect upon the Brain and nerves is destroyed. But these principles are restored by Respiration; for in passing through the Lungs, carbon is emitted through their thin air vessicles, and uniting with the oxygen of the inspired air, is evolved in the form of carbonic acid gas. Thus the blood is constantly acquiring properties which would destroy its agency in supporting life; but by this process it is as constantly purified.

Such are the physiological and chemical principles on which I have founded my opinion, as to the proximate cause of death in Suspended Respiration. The treatment of the disease will naturally result from, and be suggested by the cause. But before I proceed to state my own opinion, I shall examine the most popular Theories which have been advanced on this subject. Volumes on volumes have been written, and almost every author has started a Theory of his own: some have enlightened, others have only afforded more matter for doubt. Men of great ingenuity and ability, they have erred like great men and have supported each his own Hypothesis with a strength of argument which appeared matchless and unanswerable till you read his opponent. It has been from its own nature an object of great importance to ascertain the best mode of treatment in this disease, and to this intrinsic importance, adventitious motives have been added. The Humane Society of London have offered rewards to the most successful champion in this arduous and honorable contest. The prize has been won, only to be contended for and won again. The reason of this seemingly interminable doubt as to the proximate cause of the disease, subsisted in the imperfect knowledge and misapprehension of those functions upon which life immediately depends.

It was formerly the most prevalent opinion that death was remotely caused in Drowning, by the presence of water in the Lungs,

and that the circulation of the blood through the pulmunary arteries was by that means interrupted, which was the immediate cause of death. Others supposed water to get into the stomach, and by distention to produce apoplexy. The practice founded upon this opinion was to suspend the patient by the heels and agitate him as much as possible with the intention of exciting the action of the viscera, and evacuating the water. Though the bad effects of this practice were acknowledged by its advocates; yet they contended that remedies in some respects hurtful, should be used when the advantages arising from them preponderated. Not to mention the great number of Theories previously advanced, it will be sufficient for our present purpose to recur no further back than to the important experiments of Doctor Goodwin.

His first object was to ascertain whether death was caused by water in theLungs. For this purpose he immersed cats and dogs in coloured fluids, and in quicksilver. Eight Cats were suffocated in quicksilver; in three of which none was found in the Lungs after death; and in no case was there more than half an ounce. As the specific gravity of quicksilver is so much greater than that of water, he concluded that a much greater quantity would force itself into the Lungs. But even the greatest quantity of quicksilver taken in, was only equal in bulk, to seventeen grains of water. But more fully to ascertain the fact, he next injected two ounces of water into the trachea of a Cat. The only inconveniencies were a difficulty of breathing, and feeble pulse. Hence he concluded, that the small quantity of water which might sometimes be taken in, was not sufficient, in any case, to cause the death of the animal.* This opinion of Doctor Goodwin has been confirmed by the subsequent experiments of Messrs. Kite and Coleman. And in a number of Cats which I have dissected, after drowning, but a

* Goodwin on the connection of life with respiration.

very small quantity of water was found in the lungs. As no mention has been made by the above authors of the appearances of the Lungs, when the animal had been long in the water after motion had ceased, and as we might be induced to suppose water might be admitted from the relaxation of the glottis which ensues, I determined on making the following:

EXPERIMENT:

A Cat was drowned and suffered to remain under water twenty minutes. After motion had ceased, no air escaped from the Lungs, and on examination they were found to contain no more water than had been observed after ordinary drowning. This experiment was repeated with the same result; from which it appears that water in the Lungs, in no case, has any agency in destroying life.

Doctor Goodwin having proved that death was not caused by water in the Lungs, he could only suppose it to be from suspended respiration, but whether this effected the system mechanically or chemically, was a question unsettled. He supposed it to be chemically, that the black blood in the right side of the Heart, was unfit to stimulate the left side to action, and that the change the blood underwent in the circulation, was solely to prepare it for that purpose; that in consequence of Suspended Respiration, the blood in the left side became black, and "that the left auricle and ventricle first cease to act, from the inaptitude of venous blood to excite their contraction, and that in Drowning"—this is the immediate cause that suspends circulation—that by the contact of black blood in the left side of the Heart, its motions became weaker and weaker till they ceased; whereas, the right side being stimulated by the black blood to which it had been accustomed, continued to contract with full force. But the appearances on dissection do not correspond with the Theory of Doctor Good

win. If as he supposed the left side of the Heart ceased to act in consequence of the sedative effect of the black blood, then the left side of the Heart would be found engorged with blood, instead of the right, and the right which according to him retains the power of forcible contraction, would be found empty; for it is obvious that the blood must be lodged in the part where there is the greatest obstruction to its passage, and the least power to overcome it.

Now Doctor Goodwin has acknowledged that from his own experiments, he believes the Lungs are never entirely destitute of air, but even after the most complete expiration in Drowning or Hanging, that they contain a considerable quantity. Though I am not induced from my own experiments to believe the quantity to be very great, I am fully satisfied that they are never empty. Taking it for granted then, that there is always more or less air in the Lungs, and that there is in the blood a stimulating quality which is neutralized by carbon, I shall upon this supposition attempt to account for the accumulation of blood in the right side of the Heart. It cannot be owing to the greater thinness of the parietes, for we must suppose that each side has power proportional to the cause through which it has to propel the blood. But is it not owing to the greater impunity of the blood in the right side of the Heart than in the left? I am aware that it may be said in objection that the blood is always more impure in the right side than in the left, and that there is not a greater relative difference of impurity when respiration is stopped, than when it goes on freely. But admitting this, let us recur to another consideration, which we ought by no means to disregard.

We suppose that the stimulating quality of the blood can be completely neutralized with carbon, and this will take place when the saturation is complete. And will not this happen first in the

right side of the heart? When Respiration is suspended, blood arrives at the left side, but imperfectly purified, and is it not reasonable to conclude that it may be saturated with carbon before coming again to the right, as it passes through and imbibes carbon from the whole system? But the blood which passes from the right side of the Heart to the left, though overloaded with carbon at the moment it starts, is never completely saturated, for if so, the contraction of the ventricle would not be sufficient to propel it through the Lungs, and it passes from the right to the left side of the Heart without any new accession of carbon, as its whole course is through the Lungs, in which it has been shown that a small quantity of air remains We may rather suppose that even to the last, it receives some degree of purification in passing through the pulmonary vessels, and should conclude *a priori* that the blood in the left side of the Heart, would never be completely saturated with carbon. With this supposition experiments perfectly agree, for in six cases which I examined after death, the blood in the left auricle was more or less florid. Hence the reason why little or no blood is found in the left ventrical; for there the last stimulus is excited, and the last efficient contraction takes place.

It may be asked why, if this Theory be true, the right ventricle contracts longer than the left? The reason is obvious; the right ventricle is stimulated by warmth and distension, which would no doubt excite a feeble contraction even if the distending fluid were water. But its contractions are without power,* and though more frequent, are evidently less forcible than those of the left side while they continue. And after the left side has stopped beating, if the blood in the right side could be transmitted to the left, the left ventricle would contract, as was proved by the experiments of Bichat.†

* Le Gallois, Experiments on the principles of life.

† Physiological Researches, p. 182.

Mr. Kite supposes that in consequence of suspended respiration the motion of the Lungs cease, and a collapse succeeds, which mechnaically obstructs the passage of the blood from the right to the left side of the Heart; and that death is produced by an effect of this obstruction either on the Heart, the Lungs, or the Brain. This effect, he thinks, is not produced on the Heart, because the right side, where the greatest quantity of blood is accumulated, continues to beat longer than the left; nor on the Lungs, because their office is merely passive; and, he therefore concludes, that it can only be produced on the Brain, by a congestion of blood upon this organ, causing apoplexy.*

The objections to the opinion, that the blood is mechanically interrupted in its passage through the Lungs, will be mentioned hereafter. I shall at present attempt to show that death is not caused by a congestion of blood in the Brain. This is a theory that has not only been supported by Mr. Kite, but also by the celebrated Doctors Borehaave, Cullen, and others; and at the present day, it is believed by many physicians of the first eminence, that in Hanging, the pressure of the cord upon the superficial veins of the neck, prevents the return of the blood from the head, and produces a fatal apoplexy. If apoplexy is produced in either of the diseases under consideration, it would most probably be in Hanging, for there is the same collapse of the Lungs as in Drowning, and there is also the pressure of the cord on the veins of the neck, to prevent the return of blood from the Brain.

In reasoning from analogy, we cannot suppose that if apoplexy was produced in this disease, death would ensue in the short space of five or six minutes after the stoppage of the blood; for Mr. Kite acknowledges, that "extravasation does not take place in any part of the Brain;" and it is well known, that even in apo-

* Kite's Medical Essays.

plexy, produced by extravasation, which is of all others, the most suddenly fatal—death rarely happens so soon. But the opinion of Mr. Kite is not merely rendered improbable by analogy; it is incontrovertably disproved by experiments.

Mr. Coleman secured both the Carotids of a Dog, and in half an hour after suspended him by the neck. He died in four minutes. On examination, the vessels of the Brain were found less distended than ordinary.* This experiment has been so often repeated with the same result, that there can be no doubt of its correctness.

EXPERIMENT.

I secured the jugular and thyroidal veins of a Cat by ligatures at the same moment; no symptoms of apoplexy were apparent. At the end of twenty minutes the animal was killed, and on removing the cranium, the vessels were found much distended, but there was no extravasation. This experiment was repeated on another animal, and the jugular and thyroidal veins remained in ligatures forty five minutes—the result was the same.

EXPERIMENT.

The trachea of a Cat was laid bare, and an opening made just below the Thyroid cartilage, a cord was passed round the neck, immediately above the opening, by which it was suspended. Air was inspired through the opening in the trachea, and respiration went on without apparent inconvenience. There was no visible change in the colour of the lips, tongue or nose, and the eyes appeared perfectly natural. At the expiration of ten minutes, it was taken down, the hole in the trachea closed, and it breathed as usual. It was again suspended in the same manner, and the opening closed. It immediately struggled violently, the lips, nose and

* Coleman on Respiration, page 143.

tongue gradually turned purple, the eyes became glassy, and it appeared to be dying. At the expiration of one minute, air was again admitted into the trachea, and all symptoms of suffocation disappeared.

From these experiments is it not incontrovertably proved, that apoplexy is not the cause of death in Hanging? And is it not rendered fully evident by the last experiment, that want of air is the only cause of distress to a suspended animal, and ultimately of death?

Mr. Coleman, in his Treatise on this subject, has attempted to prove that the proximate cause of death is both mechanical and chemical; that in Drowning and Hanging, the muscles of expiration continue to act till they expel all the air from the Lungs, which they are capable of acting on; that in consequence of this exhausted state of the Lungs, their air cells collapse, which produces a mechanical obstruction to the passage of the blood in the small branches of the pulmonary vessels, and that this, together with the want of latent heat in the blood, constitutes the proximate cause of the disease.*

That the Lungs are in a collapsed state after Drowning and Hanging will readily be granted. But the collapse is not perfect. It has been proved by Doctor Goodwin, that after the most complete expiration, they contain a sufficient quantity of air to permit the passage of the blood; and I have before observed, that from my own experiments I was fully satisfied that they were never empty.

But granting for the present, that the air is *all* exhausted in the last efforts to respire, and the collapse of the Lungs complete, I shall attempt to prove, that even in this case, the blood would not be mechanically obstructed. We know that the blood circu-

* Coleman on Respiration.

lates freely in organs which are alternately distended, and collapsed; as in the Heart, Stomach, and urinary bladder—and that in other parts of the system, though the vessels are contorted and convoluted, as in the motions of the limbs, the mesentery, &c.; and though these changes take place, while the blood is flowing from the part, they neither prevent nor impede it. Judging from analogy, therefore, we have no reason to conclude that a mechanical obstruction takes place in the Lungs. And to show that it is not the case, we have not only analogical proof, but experiments to ascertain the truth directly in point. Bichat, to ascertain the truth of this doctrine, adapted the tube of a syringe to the trachea of a dog, after cutting it transversely, and suddenly emptied the Lungs of all their air, at the same time opening the caroted artery. In this experiment, the circulation, he observes, should have been suddenly interrupted, as the pulmonary vessels passed all at once from their ordinary degree of extension, to the greatest possible involution; yet the blood continued for some time to be thrown out with force by the open artery, and consequently, to circulate through the collapsed Lungs.*

But to ascertain if possible, more decisively, whether the great quantity of blood found in the right side of the Heart *was* owing to a collapse of the Lungs, I had recourse to the following

EXPERIMENTS:

The trachea of a Cat was cut transversely, and the capacity of the Lungs about half filled with atmospheric air. The trachea was then secured by a ligature. The left ventricle continued to contract forty minutes. The right ventricle continued to contract twenty minutes longer, when all motion ceased; on examination, the quantity of blood, in the right side, was to that in the left, as two to one.

* Physiological Researches, p. 174.

EXPERIMENT.

The thorax of a Cat was opened and from the pressure of the dense atmosphere, the Lungs suddenly collapsed and respiration ceased. The Heart and arteries contracted with great force, and on opening into the abdomen, the mesenteric arteries continued to pulsate distinctly. As their florid colour gradually changed to purple, their motions became feeble; but at the expiration of twenty minutes, the blood evidently circulated through the Lungs. On opening into the Heart, the right ventricle and auricles were found surcharged with venous blood, the left auricle and ventricle contained a small quantity of blood, but more florid than that in the right.

From the first of these experiments, it appears, that death ensues in Suspended Respiration, when the Lungs are not collapsed; and that the blood is found as in death from other causes, principally lodged in the right side of the Heart. From the second, that the circulation continues sometime after the Lungs are collapsed; whereas, if it was impeded by the collapse, the obstruction would be as complete at the time of the last expiration, as it would at any future period. This fact is sufficient to disprove Mr. Coleman's opinion, for he does not agree with Mr. Kite, that the circulation is impeded by a want of motion, but says, "the right side of the Heart can propel blood to the left immediately after the last expiration, independent of the mechanical action of the Lungs, and as it can perform this function after Respiration has ceased, it is probable that the Lungs have naturally no active power of propelling the blood onward."

To what has been said against Mr. Coleman's theory, so far as respects the collapse of the lungs, I shall only add one of his own experiments, by which he attempted to disprove the opinion of Mr. Kite:

" EXPERIMENT."

" The trachea of a Dog was laid bare, and secured by a ligature, and this was endeavoured to be performed at the instant an enspiration was made; in less than four minutes he ceased to struggle. On examining the Heart, we found the quantity of blood in the left, when compared to that of the right, as thirteen to twelve. A portion of the cranium was removed, and the veins of the head were evidently less distended than natural. " Here then," says Mr. Coleman, " there being no obstruction to the passage of the blood through the lungs, it could not be collected in the right side of the heart, and consequently no accumulation was found in the head, and yet this *animal died as soon as other animals from ordinary Hanging*, which carries conviction to my mind, that apoplexy forms no part of the disease."*

In this experiment of Mr. Coleman's, I have found it difficult to account for the death of the animal by any theory at that time, extant. He proves that it did not happen by apoplexy, and full as conclusively, that it did not happen by a collapse of the lungs, and we must conclude, *a priori*, that the senses of Mr. Coleman deceived him, and that the animal did not die; otherwise we must deny this poor Dog the common right exercised by all animals, of dying philosophically.

If then a collapse of the lungs is not the proximate cause of death, I shall next examine whether it is a diminution of animal heat.

Mr. Coleman supposed the motion of the Heart to depend upon irritability, which was always in proportion to the degree of animal heat; that animal heat was generated by Respiration alone; conse-

* Coleman on Respiration, page 142.

quently Suspended Respiration would be a *remote*, and a diminution of animal heat, a *proximate* cause of death.

I have already shown that the contractions of the Heart do not depend exclusively on irritability, and in some late experiments Mr. Brodie has demonstrated that animal heat is neither generated solely by Respiration, nor is it immediately essential to life. He kept alive decapitated Dogs and Rabits, two hours, by artificially inflating the Lungs, though the heat in the thorax diminished in the mean time sixteen degrees. This experiment was frequently repeated, and in every case the heat diminished faster in animals kept alive by artificial respiration, than in those of the same age and species which were suffered to die. Hence he concludes that the generation of animal heat depends upon the influence of the Brain, though by supporting respiration, life may be preserved. These experiments were repeated by La Gallois, and though he says " the results did not appear to him as regular as pretended by Brodie, the temperature was considerably reduced." If, in addition to this, we reflect that experiments are recorded in the philosophical transactions, in which, by a person being placed in a cold bath, and afterwards exposed to a cold easterly wind, the heat of the body was diminished sixteen degrees, without causing any material injury; we cannot suppose a diminution of animal heat to have any immediate effect in destroying life.

Dr. Fothergill, in his excellent treatise on Suspended Respiration, from drowning and suffocation, supposes the proximate cause of death to be " the exclusion of air from the lungs, and the extinction of irratibility." The first part of this theory is practically, but not critically correct. The exclusion of air from the lungs is the remote or exciting cause of the disease, but is not the proximate cause, according to the general acceptation of the term.

As to the second part of Dr. Fothergill's theory, viz: that which respects the extinction of irritibility, a more particular examination of it is necessary. The Doctor insists upon it with great tenacity and zeal, and introduces it for the solution of a variety of phenomena. We have already had occasion to object to the existence of irritibility, as independent of the nerves. That there is an irritibility existing in the muscles, will not be doubted; but we consider this irritability as depending, in all cases, on the *vis nervea*, which, as heretofore explained, is sufficient to account for all the phenomena of the animal economy. Why then resort to a hypothetical agent, of whose existence there was never any other proof, than that it was convenient as a medium of explanation, and helped the physiologist out of difficulties, from which he could not otherwise escape?

In proof, that the motions of the Heart do not depend upon the nerves, it has been said by some, that the heart had no nerves; by others, that it had but few, and that those were not effected by irritation.* But other anatomists, who have been either more honest, or more perspicacious, have affirmed, that the nerves of the Heart are as numerous, and are distributed in the same manner, as in the other muscles.† If, on irritating the nerves of the Heart, they do not disturb the motions of that organ, it only proves, that these nerves are *sui generis*, and sensible to a peculiar stimulus. In apoplexy, says Dr. Fothergill, all the functions depending on the nerves, are suspended; but not the motions of the heart; and this he adduces as a proof, that these motions do not depend on the nerves. But sensation is not destroyed in apoplexy; as the Brain is diseased, which is the organ of volition, that faculty is suspended, and of course has no power to direct the action of the muscles. For if the limb of an appoplectic

* Fothergill on Suspended Respiration, p. 63. † Le Gallois, 248.

person be pinched, or pricked, it will be partially drawn up. Though this motion be weak, the reason is obvious, for as Le Gallois observes, "the Medulla Spinalis is in a morbid state, after the injury or destruction of the Brain, as there is an intimate connection between them."

Dr. Fothergill supposes, that the *vis nervea* would be insufficient to support the continued action of the Heart. "It does not," says he, "like other muscles, become weary by incessant motion; neither does it become less irritable to the blood by the daily repetition of the stimulus, any more than the eye does to light the ear to sound, &c." But the Doctor seems to have forgotten, that the eye and the ear exercise their functions through the medium of nerves; and that it is a law of the animal economy, that the nerves of certain organs should be operated upon by stimuli, peculiar to themselves, and that the heart may as well be supposed to be an organ of this description, and to have nerves excited by a peculiar stimulus, as the eye or the ear. And the Doctor seems also to have forgotten, that the eye and the ear are excited by a continued stimulus, in nearly the same manner as the Heart.

EFFECTS OF SUSPENDED RESPIRATION FROM DROWNING.

When an animal is immersed in water, it immediately struggles violently, and from its disposition to breathe, air is expelled from the Lungs, as is evident from the bubbles rising through the water. As the distress for the want of air, increases with every expiration, efforts to inspire are repeated, and the expiration made more complete. During these struggles which continue a minute, and in some cases, a minute and a half, the eyes gradu-

ally assume a glassy appearance, and are somewhat protruded, the pupils are, unusually dilated, and the nose, lips, and tongue, are in some cases pale, in others, lived. After all external motion has ceased, and the animal is taken from the water, the Heart is felt to beat feebly; on pricking, or pinching the legs, they are partially drawn up, and if amputated, dark coloured blood issues from the arteries.

On opening into the Thorax, the Lungs are found much collapsed; a small quantity of frothy fluid, can generally be squeezed from them; being evidently, the mixture of the air remaining after the last expiration, with a small quantity of water, which in the attempt to inspire was taken in. The veins appear preternaturally full, and of an unusually dark colour; the right auricle and ventricle, are much more distended than the left, and are of a darker colour; both auricles and ventricles now contract uniformly, but their motions soon become weak. In about twenty minutes, the contractions in the left ventricle begin to intermit; the right auricle and ventricle, are comparatively much distended, and are of a dark purple; their contractions continue, but are feeble and ineffective, and much less forcible than those of the left side when they do occur. The right ventricle next ceases to contract, and the last motion is seen in the corresponding auricle, commonly at the expiration of an hour and a half. If after all motion has ceased, the Heart be opened, the right ventricle and auricle, and all the contiguous veins are filled with black blood, the left auricle contains aboutone third as much blood as the right, and it is of a more florid colour.

On opening into the Brain, the superficial veins appear a little more full than ordinary, but in no case is there any extravasation;

EFFECTS OF SUSPENDED RESPIRATION FROM HANGING.

When an animal is suspended by the neck, death is not so immediate as in drowning, for as observed above, in the one case motion ceases in a minute, or a minute and a half, whereas, in the other, it commonly continues five or six minutes. This is probably owing to the imperfect stoppage of the trachea in Hanging, and the admission of a small quantity of air in the efforts to inspire. This imperfect exclusion of the air, is no doubt the cause of the difference in the appearances in Drowning and Hanging, during and after death. For in Hanging, the mouth and nose gradually assume a livid hue, and before death, are of a dark purple colour, the eyes are more prominent than in Drowning, and the muscles in some cases are stiff.

On opening into the chest, the Lungs are collapsed the same as in Drowning, they contain but a small quantity of air, and the Heart, and bloodvessels in both cases exhibit nearly the same appearance.

The veinse of the Brain are a little more turged than after Drowning, but as in that case there is no extravasation.

After describing the changes effected by Drowning and Hanging, and the appearances of the vital functions after death, we may conclude, that whatever is the proximate cause of death in the one, is also the proximate cause of death in the other; that the trifling difference in the appearances on dissection, is owing principally to the difference, both of the medium in which the animal is destroyed, and the time in which it is dying.

In Drowning and Hanging, the ingress of air into the lungs is interrupted, and their mechanical action arrested. The effect

upon the system is immediate; for upon this mechanical action, is that chemical process founded, which is indispensable for the purification of the blood. The blood now returns to the right side of the Heart, and is again propelled through the lungs. A portion of the carbon is disengaged by uniting with the small quantity of oxygen yet remaining; but the quantity is so small, that the change is imperfect. The blood now begins to loose its influence upon the nervous system; but where, and in what degree, is this effect produced? Is it as some have supposed upon a particular organ? We presume the paralysis to be limited only by the extent of the nervous power. If it has more effect upon one side of the Heart than the other, it is only because in that side, its impurity is greatest. For though every part of the body suddenly feels the effect, it is exclusively through the medium of the nerves, and the failure of excitement is always in proportion to the change of colour in the blood, that is in proportion to the accumulation of carbon. *Hence I conclude the Proximate Cause of the disease, to be an excess of carbon in the blood.*

Whether this effect of carbon on the nerves, is negative or positive, mediate or immediate, may be doubted; or in other words, it is doubtful, whether carbon paralizes the nerves themselves, or destroys some stimulating quality in the blood, and causes it to fail in its usual effect in exciting the nervous energy. But I am inclined to the latter opinion, namely: that the carbon neutralizes some quality of the blood; for when Respiration is restored after being suspended, and the carbon is thrown off, the nerves instantaneously recover their tone: whereas, if the influence upon them had been positive, their tone would not be instantaneously, but gradually recovered. But in either case, where does this deleterious principle first exert its influence? It first comes in contact with the Lungs and the Heart; the *vis nerva* feels the want of its accustomed stimulus—the power of the heart

begins to diminish—the carbonized blood enters the coronary arteries, and every fiber of the Heart feels the effect. No sooner is the blood propelled through the system, than the Brain and Spinal Marrow begin to loose their influence upon the Heart. No longer excited by the arterial blood, upon which their energy depends, the effect is now as extensive as the nervous system. The glands and absorbents loose their power of action, and the secretions and excretions are stopped. The nerves of the Heart, accustomed to the stimulus of the blood, continue to excite it to contraction, after the energy of every other part is destroyed. The left ventricle, which, for reasons before mentioned, is most powerfully stimulated, forces the blood through the arteries, it returns slowly in the veins, incapable of exerting a contraction, sufficiently forcible in the right side of the Heart to propel it through the Lungs, it accumulates in the veins, and right side of the Heart; and by warmth and distention, excites a feeble motion in the right auricle and ventricle, till life is totally extinguished.

TREATMENT.

It would be highly interesting and important, to ascertain precisely how long Respiration may be suspended without destroying life. "The last signs of life" says Doctor Le Gallois, "are sensation and the circulation of the blood." We have already said that Doctor Le Gallois, supposed life to be produced, and maintained by the impression of arterial blood upon the Brain and medulla spinalis, or by a principle, resulting from this impression.* Life, therefore, can only be restored in those cases, where the Heart has sufficient power to propel the blood to the Spinal Marrow, that the Spinal Marrow may be excited again to give energy to the Heart. But there is no infallible criterion, which will enable us to determine the degree of nervous energy remaining in

* Experiments on the Principles of Life.

the Heart. Much will depend upon the age and constitution of the person. Cases are related by the Royal Humane Society, of recoveries, thirty, thirty five, and in one case, forty five minutes after submersion. But in others, after the utmost exertion the patient died, though he had been in the water but three minutes.

Seldom is a person recovered after he has been under water fifteen minutes. Either no credit is to be given to the accounts of certain early writers, or we must conclude the people of their time to have been amphibious. Kunckel, says, " that in Sweden, no one doubted the possibility of restoring the life of a person who had been under water eight days;" and Burmann, relates a case, where " a person continued under water seven weeks, notwithstanding, which, he not only recovered, but enjoyed health many years after."

We may, however, form some opinion, as to the probability of a recovery, when we can obtain no information respecting the time the body has been in the water. If pricking or pinching the limbs excites any motion; if they are flexible, if on placing a thermometer under the tongue, we find that animal heat is not all extinguished, there is hope of recovery. But if the limbs and body be stiff, the countenance cadaverous, the eyes dim and sunken, and the heat of the body extinguished, we have no more encouragement to attempt Resuscitation, than after a natural death. But if all the circumstances attending the submersion can be ascertained, it will aid us much in forming an opinion as to the probable result of the case. It is important to know whether the person was timid, intoxicated, or subject to fits, or whether he fell from a great height. The temperature of the water ought also to be taken into consideration. But we would tolerate no inquiries at the expense of time. The most important, nay the essential means of recovery, first to be used, is in all cases the same.

We have been recommended to convey the patient carefully to the most convenient place for using the means of recovery; but if we reflect that the force of the Heart diminishes with every pulsation, and that if life is restored, it can only be done by restoring the circulation, we shall never be driven from the spot, except by intensity of cold, until respiration is restored.

I shall not attempt to detail the numerous modes of treatment that have been recommended and adopted, by various writers on this subject. If the cause which has been assigned for the disease be correct, the treatment will be simple, viz. those means that are immediately essential to restore Respiration. Neither the symptoms that will exist, nor the treatment which will be necessary after Respiration is restored, can be anticipated. The one will in all cases naturally result from the other.

When a person is taken from the water, unless we know he has been immersed so long that there are no hopes of his recovery. we would immediately attempt to renew Respiration, by artificial means. This we would do with the first instrument that came to hand, by which air could be conveyed into the Lungs. A bellows would be prefered, to any article in common use. In case we could procure no instrument for inflating the Lungs, we would make use of Astley Cooper's expedient, and by pressing on the sternum and ribs, compress them, when by lifting the hands, those parts by their elasticity will restore themselves, the chest be expanded, and the air rush in.

We have supposed the cause of the disease, to be excess of carbon in the blood, that while the circulation continued, a small quantity was emitted to unite with oxygen gas, in the Lungs, and we must conclude, therefore, that the air inthe Lungs, is not only absolutely unfit for Respiration, but positively deleterious, the oxygen gas being changed into the form of carbonic acid gas. This

deleterious air, can only be expelled from the Lungs, by inflating them with pure air, with which it will mix, and gradually be thrown out by artificial expiration.

In order to inflate the Lungs, we would place the body in a convenient posture, with the head elevated, and introduce the pipe of a bellows into one nostril, while the other nostril and mouth were closed by an assistant. The inflation should be gradual—after which the air should be pressed out by the assistant, and this process continued. To prevent the passage of the air into the stomach, and direct it into the trachea, the assistant should press upon the thyroid cartilage, and to raise the epiglottis for the admission of the air, the tongue may be pulled forward. This process should be commenced as soon as the patient is taken out of the water, and no other means should ever be suffered to interpose a moments delay. Many things may be done, which are in some degree advantageous, but nothing can compensate for the neglect of inflating the Lungs. Thus the wet clothes should be stripped off, and the body should be wiped dry, wrapped in flannel, and rubbed with a flesh brush, or with the hand.

Electricity will be found very beneficial in stimulating the action of the Heart. It should be communicated through the region of that organ in slight shocks; and in order to aid the purification of the blood, the excitement should be given while the Lungs are inflated. Care should be taken that the shocks be not too violent. It is well known from experience, that a very powerful shock paralizes, instead of stimulating the energy of the heart.

When the body has been taken from under the ice, and generally whenever we have reason to believe that it is very much chilled, we should be cautious in the application of warmth. We

would, in such cases, endeavour to place the patient in a temperature, a few degrees higher, than that from which he had been taken, and increase it as warmth returned to the body. The temperature of the body may be best regulated by a bath, in which the patient ought always to be placed when it can be procured. We suppose that artificial Respiration has been kept up, and been made to resemble natural Respiration as much as possible, both in manner and degree, that the body of the patient has been wiped dry—that he has been placed in a proper temperature, and that his skin has been gently rubbed with the hand, or with a flesh brush. These are the means on which we rely for Resuscitation; and if these fail, after a faithful trial of about three hours, the case is hopeless. But persons are frequently taken from the water in a lifeless state, who have been otherwise seriously injurged, than by drowning; as by a fall from a great height, by intense cold, &c. and when we have reason to conclude, that such has been the case, we shall of course, vary our treatment.

As to bleeding, emetics, enemas, &c. it is sufficient to say *generally*, that we consider all depleting remedies as injurious in the first stage of cure that is, before the full re-establishment of Respiration. Even if bleeding should remove the black blood from the right side of the Heart, which we much doubt, it would not restore its arterial quality, on which life immediately depend We shall not point out the path to be pursued in the second stage of cure. The treatment will be regulated by the symptoms of the patient, and the judgment of the physician. If oxygen could be procured, it would unquestionably be a much more probable means of purifying the blood, and restoring the circulation, than common atmospheric air; but we cannot expect, in ordinary cases, to be able to procure it.

TREATMENT IN HANGING.

In attempting to restore life, after Hanging, the means we would practise, are much the same as above described. The most important thing to be done, is to inflate the Lungs, and to establish artificial Respiration. Bleeding is very generally recommended, but as we have reason to believe, from our experiments, as well as those of others, that apoplexy seldom takes place, we would bleed only in cases where there is more than ordinary reason to believe, that either apoplexy, or a turgescence of blood in the Brain has ensued, as where the patient has been long hanging, or was uncommonly heavy. In such cases, we would open a jugular vein. But in the mean time, artificial Respiration should never be intermitted; and we wish it to be well understood, that we consider artificial Respiration as the great and paramount remedy, as well in Hanging, as in Drowning, and all other remedies, as merely subservient to it. To stop artificial Respiration, for the purpose of practising any other expedient, would, in our opinion, be as inexpedient, as to open a vein, or apply a blister in an ordinary case, and at the same time, to suffocate the patient, by immersing his head in water.

Before I conclude, I cannot deny myself the pleasure of expressing my sentiments towards the Professors of this University. The zeal which they have shown for the improvement of their pupils, and the ability with which that zeal has been seconded, must have left an impression upon the mind of every student, which time will not obliterate. It is a subject on which I feel more than I shall venture to express—a subject on which the heart would dictate, without any toil of the intellect. When I contemplate the satisfaction with which I shall, through the whole course of my life, look back on the time I have spent in this

University, I cannot forbear to take a parting glance at the advantages I have enjoyed, and to return thus publicly, my thanks to the gentlemen, whose instructions have contributed to my improvement, and whose benevolent condescensions, have truly made the paths of wisdom " ways of pleasantness."

FINIS.